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THE EFFECT OF END-RESULT SPECIFICATIONS ON BRIDGE DECK WATERPROOFING IN ONTARIO

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The Effect of End-Result Specifications On Bridge Deck Waterproofing in Ontario

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ABSTRACT

The use of a form-in-place membrane of hot-poured rubberized asphalt has been the almost exclusive method of bridge deck waterproofing in Ontario since 1972. Poor workmanship and inspection resulted in several sub-standard waterproofing projects.

In 1983 the Ministry of Transportation, Ontario, introduced an interim acceptance plan for membrane thickness based on random sampling of lots and sub-lots. This plan forced the Contractor to be responsible for process control and the Ministry to perform acceptance testing upon completion of the work.

The data gathered under the interim acceptance plan was analyzed and used to develop a full statistical end-result specification (ERS) for membrane thickness. This ERS was implemented in 1986. In 1987, a material quality component was added.

This paper presents data which demonstrates the impact of ERS on membrane thickness over the period from 1983, and on membrane quality from 1986 up to the end of the 1989 construction season.

It is concluded that end-result specifications have had, and are continuing to have, a significant positive impact on improving bridge deck waterproofing in Ontario.

INDEX

BACKGROUND	1
COMPONENTS OF END RESULT SPECIFICATIONS	3
ERS PHILOSOPHY	4
IMPLEMENTATION	7
DATA ANALYSIS	8
DISCUSSION	14
CONCLUSION	16
REFERENCES	16
APPENDIX (Special Provision)	17

ABRÉGÉ

L'utilisation d'une membrane d'asphalte caoutchoutée posée à chaud se formant sur place a été pratiquement la seule méthode d'imperméabilisation des tabliers de ponts utilisée en Ontario depuis 1972. Une main-d'oeuvre et une inspection de piètre qualité ont cependant résulté en plusieurs projets d'imperméabilisation ne répondant pas aux normes.

En 1983, le ministère des Transports de l'Ontario a mis au point un plan d'acceptation officiel provisoire relatif à l'épaisseur de la membrane et basé sur un échantillonnage au hasard de lots et de sous-lots. Ce plan a forcé les entrepreneurs à être responsables de leur contrôle de processus et le ministère à effectuer des essais d'acceptation une fois les travaux terminés.

Les données recueillies en vertu du plan de réception provisoire ont été analysées et utilisées dans l'élaboration sur une base statistique des spécifications a posteriori. En 1987, on lui ajoutait un élément portant sur la qualité des matériaux.

Ce document présente des données démontrant l'effet du cahier des charges final sur l'épaisseur de la membrane depuis 1983 et sur la qualité de la membrane de 1986 à la fin de la saison de construction 1989.

On en conclut que les cahiers des charges finaux ont eu et continuent d'avoir un effet important sur l'amélioration des l'imperméabilisation de tabliers de ponts en Ontario.

BACKGROUND

In the late sixties and early seventies there was much concern over the durability of the exposed concrete bridge decks constructed in Ontario since 1965. Extensive corrosion of deck reinforcement, aggravated by insufficient concrete cover, was resulting in spalling of the deck surfaces. Salt brine was also leaking through deck cracks allowing access for chlorides to steel deep inside the deck. Of particular concern was the potential corrosion of stressing cables in post-tensioned structures.

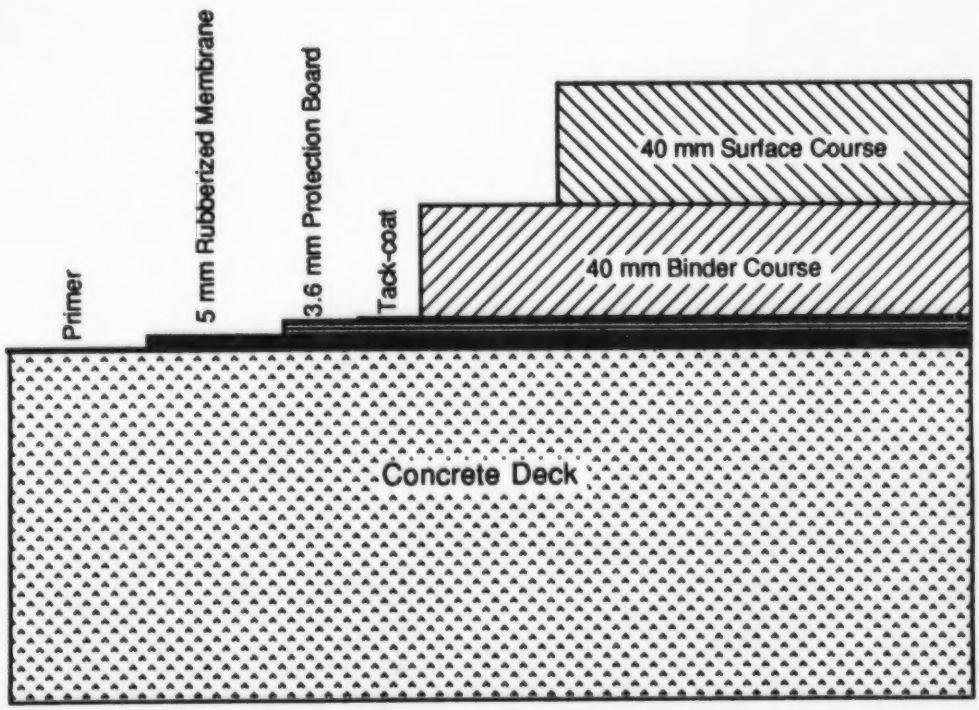
These concerns resulted in a change in policy from exposed concrete riding surfaces to one of waterproofing and paving all new structures. Old bridges would also be waterproofed and paved as part of reconstruction or resurfacing contracts. A new system using hot applied rubberized asphalt (Asphalt Membrane) was approved for use on all structures. The asphalt membrane system consisted of a form-in-place membrane, 5 ±1 mm thick, covered by 3.6 mm thick protection boards and two 40 mm lifts of hot mix pavement. See Figure 1.

The quality of materials, for the most part, remained within specified requirements due to a formalized programme of sampling and testing, but the quality of workmanship generally deteriorated between 1978 and 1983. This was principally the result of contractors skimping on membrane thickness due to a very competitive market.

By 1983 it became evident after several substantially sub-standard waterproofing jobs (excessively thin membrane resulting in leaking decks) that a formalized system of inspection and reporting was required to ensure quality workmanship. By that time the Ministry had already made a commitment to the development and implementation of statistically based end result specifications (ERS). In keeping with this objective, an interim acceptance plan for waterproofing membrane thickness was devised in 1983. The plan consisted of a formalized system of testing, and acceptance or rejection. Bridge decks were divided into lots of 600 m^2 or less for acceptance. After the completion of the work in the lot, each lot was divided into 10 equal sublots and the thickness of the membrane was checked and recorded at a randomly selected location in each sublot. A form was developed on which the inspector would record the random locations and thickness measurements and sign the document. A copy of this form was then forwarded to Head Office for the development of a data base.

The 1983 data was rendered suspect when it was discovered that some inspection staff had been making the measurements as the work progressed (entering into the process control) instead of waiting until the contractor completed the lot. Construction inspection staff were advised through correspondence and seminars to remove themselves from the process control and only make measurements after the completion of a lot. The 1984 and 1985 data was considered valid and was used to develop a final ERS acceptance plan for thickness including price reduction for borderline work. The development of this ERS is detailed in Reference 1. This system was implemented in all contracts awarded after April 1986.

FIGURE 1: ASPHALT MEMBRANE WATERPROOFING SYSTEM



COMPONENTS OF END RESULT SPECIFICATIONS

The general goals of ERS, as accepted by the Ministry of Transportation, Ontario, are: separation of responsibilities for process control and for acceptance, recognition of inherent variability in materials and testing, allowance for the acceptance of material that does not quite meet contractual requirements, and provision for re-testing of challenged test results.

- Separation of Responsibilities

Separation of responsibilities is accomplished by having well defined specifications that define the Ministry's and the contractors' responsibilities. Ministry staff who in the past have instructed the contractor on process, equipment, etc. were instructed to remove themselves from process control and to concentrate on acceptance. In the case of waterproofing, all thickness measurement acceptance checks are made after the work is done, not while it is in progress; this encourages the contractor to measure the thickness as the work advances.

- Recognition of Variability

Variability is always present in materials, in sampling and in testing. To accommodate this variability, the specification must recognize its existence so that whatever is specified can be constructed by a contractor exercising reasonable process control.

- Acceptance of Borderline Materials

The acceptance system recognizes that even though a material does not meet contractual requirements it still has value, especially when test results show that the material is marginally outside the requirement limits.

- Re-testing

Allowances are made in the system for the re-testing of test values challenged by the contractor. Usually when a test is challenged and a new set of values is obtained, the challenged values and the new tests are combined and used for acceptance. In the case of bridge deck waterproofing the challenged values are discarded and only the re-test values are used. Re-test values may not be challenged.

ERS PHILOSOPHY

The following guide-lines were applied in developing the acceptance plan: membrane meeting all requirements would be paid for at full price, membrane not meeting all requirements but not rejectable would be paid for at a reduced price, rejectable membrane in respect of thickness would not be paid for until the contractor made the necessary repairs and brought the lot within the acceptable limits, rejectable membrane in respect of quality would result in no payment for the lot.

The acceptance plan adopted contains the following criteria.

- Acceptance is based on lots. A lot is defined as a full bridge deck or part of a bridge deck with an area of 600 m^2 or less.

- Each lot is divided into ten equal sub-lots; three thickness measurements are made at a random location within each sub-lot and the three readings are averaged and reported as one thickness measurement.

- A sample of material is obtained at a random time in each lot from the contractor's melter for quality testing.

- Payment for material thickness is made at the contract bid price whenever the lot has a mean thickness of 5.0 ± 1 mm and zero per cent defective.

- A reduced payment is applied whenever the mean thickness is greater than 4.0 mm and the per cent defective is from 0.1% to 5.0%. The relationship between price adjustment and per cent defective is not linear but elliptical in form so that the penalty is very low for work that almost meets specified requirements but becomes increasingly severe for work which deviates further from requirements.

- The payment adjustment schedule for thickness is set at 100% for 0.0% defective down to a minimum of 50% payment at 5.0% defective.

- The lot is considered rejectable when the mean thickness is less than 4.0 mm, or when the per cent defective is greater than 5%.

- With a mean thickness greater than 6.0 mm, the lot can be considered rejectable when geometrics, traffic volumes etc. are expected to result in distress such as pushing and rutting.

- The contractor must repair all lots which are rejectable for membrane thickness, and has the option of accepting a price reduction or repairing borderline lots. The extent of the repair is left to the contractor, however any protection board removed must be replaced with a new protection board. Once repairs are made the entire lot is re-evaluated.

- The payment for quality is based on accumulated adjustment points for each test criteria outside specification limits in Table 1.

- The lot will be subject to a price adjustment in respect of quality when the accumulated adjustment points (from Table 1) are 1 to 25. The lot will be rejectable and will receive no payment if the accumulated adjustment points exceed 25.

- The payment adjustment factor for quality is applied to the adjusted price for thickness to determine the final payment for a lot.

- Re-testing is permitted if any test value is challenged. For thickness, ten readings at new random locations are taken in the presence of the contractor and the results are binding on both parties. For quality, the laboratory tests are re-run on the remaining portion of the original sample and the results of the re-test are binding on both parties. However, if the re-test results in either a price adjustment or rejection, the contractor will be charged $500.00 for the additional testing.

TABLE 1: MEMBRANE QUALITY ADJUSTMENT POINTS

Test	Specification Limits	Adjustment Points
Cone Penetration at 25°C (0.1 mm)	Max 110	0.1 per 1
Cone Penetration at 50°C (0.1 mm)	Max 160	0.1 or 0.2 per 1 *
Flow at 60°C (mm)	Max 3	0.5 per 1
Low Temperature Flexibility at - 25°C	Pass	5.0 for Failure
Toughness (Joules)	Min 5.5	0.5 per 0.1
Toughness/Peak Load (Joules/Newtons)	Min 0.040	0.5 per 0.001

* If the Cone Penetration at 50°C is greater than 160 but less than or equal to 200 the factor is 0.1, or if it is greater than 200, the factor is 0.2 per unit that exceeds the specification limit.

The acceptance procedures to estimate the per cent defective and possible price reduction would have involved calculating the mean and the standard deviation of the lot, calculating the quality index, applying the quality index to a table to determine the per cent defective and finally applying the per cent defective to a formula to determine the price adjustment. To simplify this procedure an acceptance table was developed (Table 1 in appendix). To use the table, the lot mean and lot standard deviation must be computed taking care to follow proper rounding procedures, then using the values, determine from the table whether the lot is acceptable, borderline or rejectable. If the lot is borderline, the price adjustment, in the form of a price adjustment factor, is read directly from the table.

IMPLEMENTATION

Membrane Thickness

Prior to implementation of the thickness component of the ERS system, all members of the Ontario Waterproofing Contractors Association, plus all waterproofing contractors who were not members of the association but who had worked for the Ministry during the previous 4-5 years were invited to attend a presentation on the new acceptance procedures in December of 1985.

The development background of the new specification, the method to be used to apply the specifications, the desire of the Ministry to obtain a better product, and the expected impact on the industry were discussed. The impact of the ERS on each individual contractor, based on past performance, were given to each contractor privately and, if requested, discussed in detail. Understandably, some contractors were concerned while others saw the new system as an opportunity to receive fair payment for their work in that all contractors would be treated in a uniform, fair and equitable manner. The thickness component was introduced by Special Provision into contracts awarded after March, 1986.

Membrane Quality

Asphalt Membrane Waterproofing is a proprietary formulation of polymer modified asphalt and fillers manufactured to meet the requirements of the Canadian General Standards Board standard CAN/CGSB-37.50M. This standard permits a maximum cone penetration of 200 @ 50°C (ASTM D1191). The Ministry considers material that approaches this limit too soft for application on decks with superelevation or on a grade. For this reason, in 1986, the Ministry set a limit of 160 penetration @ 50°C for material to be used on Ministry bridge decks. As a result of this change, two manufacturer's products failed this requirement on a significant number of quality assurance samples obtained from job sites in 1986.

Due to the high percentage of material samples failing one or more quality test criteria in 1986, a decision was made to develop a price adjustment scheme for nonconforming materials. The various manufacturers were advised of their products' failures, and that a price adjustment scheme was under development. In March of 1987 a formal presentation was made to the Waterproofing Contractors Association outlining the proposed price adjustment system for membrane quality; the product manufacturers are members of this association. Although the price adjustments would directly affect the contractors, each manufacturer was given privately an analysis of the impact of the specification for material supplied the previous year.

Contracts awarded after August 1987 contain the ERS special provision which adjusts price for both thickness and quality non-compliance.

DATA ANALYSIS

Membrane Thickness

Prior to 1983 a formal acceptance system did not exist and a record of membrane thickness measurements was not kept. The first formal recording of membrane thickness measurements occurred in 1983 under the interim acceptance plan. This data was discarded when it was discovered that Ministry personnel had been entering into the process control activity on a significant number of projects. Data gathered in 1984 and after is considered valid and representative of contractor process control.

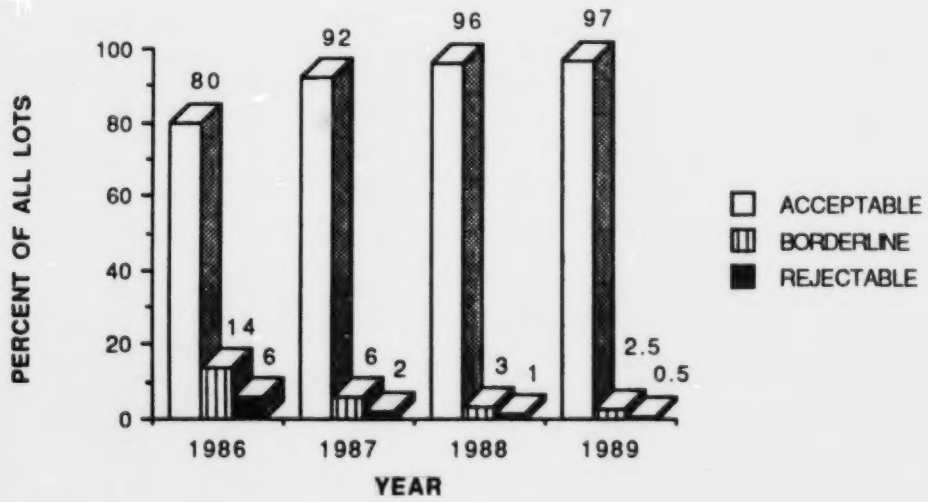
Prior to the introduction of the interim acceptance plan many bridge decks were waterproofed with an average thickness less than the minimum requirement of 4 mm. The interim plan (1983) and the subsequent ERS (1986) had a significant impact on improving membrane thickness as may be seen in Table 2. In fact, the industry is now averaging very close to the target value of 5.0 mm. Contractor process control has also had the effect of reducing membrane thickness variance as evidenced by the gradual reduction in the average lot standard deviation. In the last three years this value has not changed (0.63) and is likely typical of a contractor exercising "good" process control.

TABLE 2: ANNUAL MEMBRANE THICKNESS SUMMARY

YEAR	NO. OF LOTS	MEAN THICK. (mm)	AVG. LOT ST. DEV.
1984	261	4.7	0.75
1985	306	4.8	-
1986	157	4.9	0.70
1987	254	4.9	0.63
1988	319	4.9	0.63
1989	189	4.9	0.63

Average values can be misleading, since they give little indication of the extremes. When the data is viewed on the basis of acceptable, borderline or rejectable lots, a different picture emerges. Figure 2 depicts the change in these three categories since the implementation of the thickness component of ERS in 1986.

FIG. 2: MEMBRANE THICKNESS COMPLIANCE



Fourteen waterproofing contractors (identified by letter) shared the work over the years 1986 to 1989. Figure 3 demonstrates how the work was divided between the contractors and depicts the relative performance of each contractor. All contractors did not perform work for the Ministry in each year. Contractors "A" "L" and "M", who each constructed a significant number of lots over the four year period, had little or no defective work whereas contractors "B" "C" "I" and "J" had substantial defective work. Contractor "M", who performed work in each of the four years, exercises excellent process control and had only one borderline lot in that four year period.

Of the ten contractors performing waterproofing for the Ministry in 1989, five had all lots accepted at full price, whereas only three out of eight did in 1986. Three of the four contractors with an average standard deviation less than 0.60 in 1989 (excellent process control) "A","C" and "P" had all lots acceptable. Individual contractor statistics for 1989 are presented in Table 3.

FIGURE 3: CONTRACTORS PERFORMANCE 1986 TO 1989

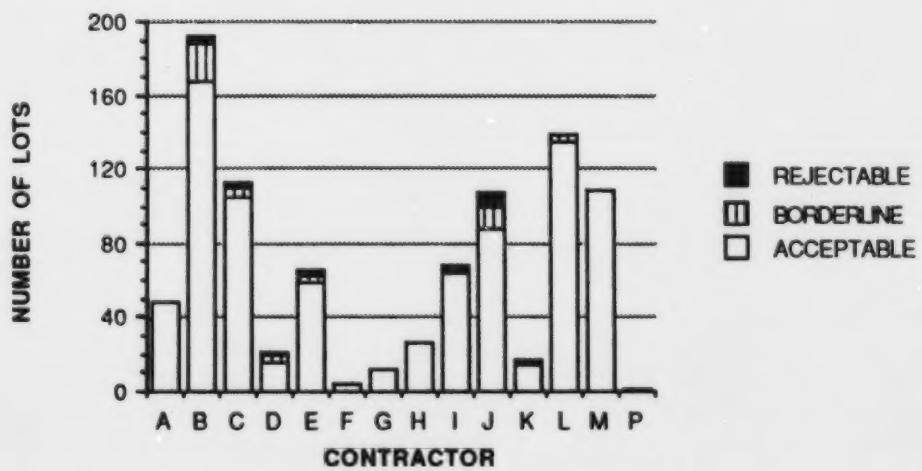


TABLE 3 : 1989 CONTRACTORS' STATISTICS

CONTRACTOR	MEAN THICKNESS (mm)	AVERAGE LOT ST. DEV.
A	4.83	0.57
C	5.50	0.55
D	4.70	0.88
E	5.07	0.64
I	5.13	0.86
J	4.92	0.68
K	4.66	0.67
L	4.90	0.61
M	4.83	0.58
P	4.30	0.50

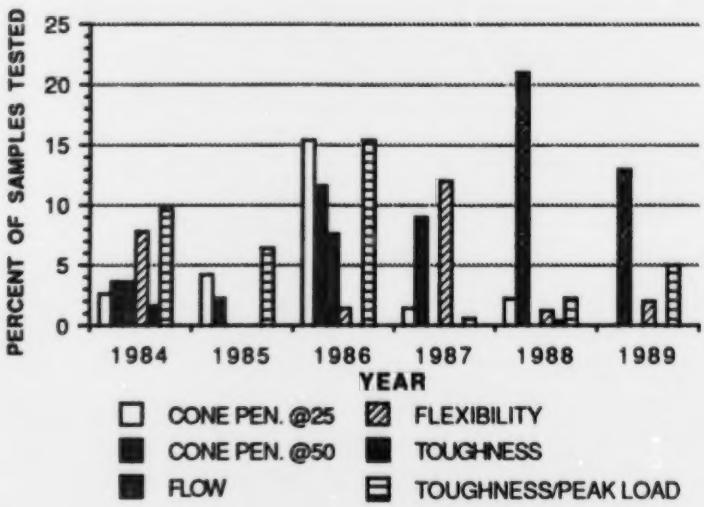
Membrane Quality

Up to 1987, Ministry policy required that a material sample be obtained from the contractor's melting kettle on each bridge waterproofed and sent to the Engineering Materials Laboratory for quality testing. Prior to 1984, sample quality test reports were sent to the Regional Construction Office with a copy committed to file at Head Office. With the acquisition of micro-computers in the Engineering Materials Office, an annual material quality data base was commenced in 1984. With this data base, periodic print-outs allowed for a rapid review of overall compliance to the six quality parameters routinely tested. The ease with which data could be summarized and analyzed resulted in test summaries being sent to those manufacturers with quality problems and the increased communication was credited with a decrease in quality problems in 1985. However, in 1986 problems with material quality significantly increased, due in part to the change in the cone penetration requirement at 50° C and, as claimed by several manufacturers, due to changes in the raw ingredients used to formulate their products.

In 1987 a quality component was added to the existing thickness ERS in order to provide an incentive for the industry to consistently supply quality membrane to Ministry work. This component requires a quality sample to be taken at random from each lot constructed whereas only one per bridge was required previously. The change in penetration requirement was of particular concern to two manufacturers

whose products often exceeded the new limit of 160 penetration. As a result, one manufacturer formulated a new product for Ministry applications in 1987 and the second manufacturer reformulated their product in 1988. Figure 4 demonstrates in the form of column charts, the percentage of samples tested failing each quality criteria from 1984 to 1989. It should be noted that any given sample may fail more than one test.

FIGURE 4: HISTORY OF QUALITY TEST FAILURES

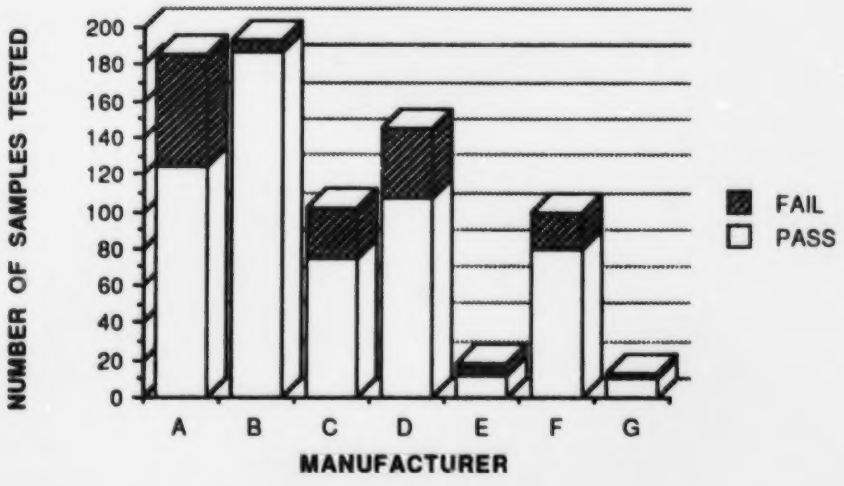


Due to Ministry financial constraints, a hiring freeze and staff shortages in the laboratory in 1988, it was not possible to test the large number of samples being generated by the ERS quality component. A decision was made to test a representative number of samples from each bridge and, if a failure occurred, all the samples from that bridge would then be tested. This resulted in a disproportionate number of tests of one manufacturer's product because of problems with the requirement for cone penetration at 50° C. The high percentage of samples failing this requirement is biased because of the concentrated testing of this one product: if all the samples received in the laboratory had been tested, the percentage failing the requirement for penetration at 50° C would have been significantly lower.

In 1989, all samples but one (unidentified) were tested, representing material from four manufacturers. Eighty two percent of the samples met all test criteria with 18% failing one or more of the quality tests. Thirty one samples failed, resulting in a price reduction for the lots represented. The failures were limited to three of the six quality criteria, cone penetration @ 50° C, flexibility and the ratio of toughness to maximum load. The Price Adjustment Factors ranged from a low of 0.915 to a high of 0.998 with an average of 0.975.

In the years 1984 to 1989, membrane supplied to Ministry projects has come from seven different manufacturers. Figure 5 identifies these manufacturers by letter and shows the proportion of samples passing all quality requirements and those failing one or more. In this Figure, it can clearly be seen that manufacturer "B" has been the major supplier of material over the five year period and has had the least quality problems. In 1988, manufacturer "B" supplied the largest proportion of membrane but was subjected to the lowest frequency of testing on account of not having any quality failures.

FIGURE 5: MANUFACTURERS' QUALITY HISTORY, 1984 TO 1989



DISCUSSION

Material Thickness

When the statistical acceptance system involving price adjustment for thickness was first introduced, it was said by some contractors to be too restrictive or even unattainable.

The continuing improved level of compliance from a low of 80% in 1986 to 97% in 1989 demonstrates that contractors can work to the requirements of the acceptance system. The per cent compliance will likely continue to improve slightly as contractors gain experience in exercising process control.

When the statistical acceptance system involving price adjustment for thickness was first introduced, waterproofing contractors were concerned that the rough surface on some old bridges would adversely affect their chances of full payment even with excellent process control.

The Ministry made a commitment to improve the surface of a rough existing deck or waive the statistical acceptance based on per cent defective. Instead, acceptance would be based on mean thickness only, provided all material was found to exceed 3 mm in thickness.

Over the first two years there were a few decks where Ministry staff employed the price adjustment system and the contractor claimed it should not have been applied due to excessive roughness of the deck. This resulted in successful claims for extra compensation by contractors.

For the 1988 construction season, the Structural Office, in co-operation with the Engineering Materials Office, developed minimum standards for an existing deck that is to be waterproofed, along with criteria for waiving the statistical acceptance system when these standards would not be met. No serious controversy between any Contractor and the Ministry on this issue was reported in 1988 or 1989.

Material Quality

When the quality component of the ERS was introduced in 1987 both waterproofing contractors and material manufacturers complained that if a sample fails a test, there can be controversy as to whether the product was non-complying as supplied or whether it was adulterated or damaged by overheating in the hands of the contractor.

Some manufactures have in fact claimed that "failure" of their samples was caused by the contractor, and the manufactures have lobbied the Ministry to sample the material before on-site heating. The Ministry has denied this request since it is the quality of the product in-place that is important.

Although not fully in effect in 1987, the fact that the Ministry took this price adjustment initiative appears to have had a positive impact on the quality of material applied to bridge decks in that year. The percentage of samples failing any test criteria dropped from 47% in 1986 to 20% in 1987. With the price adjustment component for quality in effect for all 1988 contracts it was expected that quality compliance would significantly improve in 1988. It actually appears worse. This was principally because one manufacturer's product frequently failed the cone penetration requirement at 50°C and was therefore subject to a higher frequency of testing.

The manufacturer claimed that the reheating of the product in the laboratory caused an increase in penetration which was sufficient to put it out of specification. The Ministry confirmed through laboratory testing that there was an increase in penetration on reheating this particular product. However, it is standard practice to reheat material in the contractor's field kettle and this action could also put the material out of specification. The Ministry has taken the position that no special consideration will be made for this product since all others are subject to the same reheating in the laboratory.

In 1989 there was still a high percentage of samples failing the quality tests, (18%) principally the cone penetration at 50°C requirement. Although this is an unacceptable level of compliance, the failures were however to a large extent only marginal. It has been suggested that the adjustment points for cone penetration are not high enough to provide a satisfactory incentive to the industry to comply with the requirements.

CONCLUSION

The introduction of end result specifications for the acceptance of bridge deck waterproofing has had, and is continuing to have, the desired impact of improving the quality of this important item of work.

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APPENDIX

SPECIAL PROVISION - BRIDGE DECK WATERPROOFING

Bridge Deck Waterproofing - Item No.

1.0 Scope

This special provision amends the definitions, quality assurance and basis of payment requirements of OPSS 914 by the addition of the following:

2.0 Definitions

For the purposes of this special provision the following definitions will apply:

Lot: is defined as a single bridge deck, or part of a bridge deck, with a surface area of 600 m^2 or less. Decks larger than 600 m^2 shall be divided into the least number of equal sized lots of 600 m^2 or less. Decks split longitudinally for staged construction shall be treated as separate decks. The exact limits of each lot will be determined by the Engineer.

Sub-lot: is defined as approximately 1/10th of a lot.

Mean: is defined as the arithmetic average of the test results within the lot.

Standard Deviation: is defined as the square root of the sum of the squares of the deviation of each test result from the mean, divided by 1 less than the number of test results.

Random Location: is defined as a location determined by the Engineer based on random numbers, or, if protection boards are used, it means the exposed corner of a protection board closest to that location.

3.0 Quality Assurance

The Engineer will determine the acceptability of the waterproofing by determining the membrane thickness and the membrane quality on a lot-by-lot basis.

3.1 Sampling and Testing

3.1.1 Thickness

The Engineer will obtain a test result from each sub-lot. Each test result will consist of three measurements taken at the corners of an imaginary triangle centred about the random location. The sides of the imaginary triangle shall be approximately 0.1 m. The three measurements will be averaged, rounded to the closest 1 mm and reported as one test result. The measurements will be made according to current Ministry procedures and will be made after the Contractor has completed the lot, including the placement of protection board where applicable.

3.1.2 Membrane Quality

One 4 L sample of membrane, from each lot, shall be drawn by the Contractor from the heating and mixing kettle and placed in a container supplied by the Engineer. The time of sampling will be determined by the Engineer and will be based on random numbers.
The sample will be delivered by the Engineer to a testing laboratory. The sample will be split into two approximately equal parts; one part will be tested immediately and the other will be retained for possible re-testing. If the tested part passes all criteria the remaining half will be discarded. If the tested part fails any of the specification requirements, the retained part will be kept for 30 calendar days after the contractor has been notified of the test results. If the contractor requests re-testing within this time period, the retained part will be used for this purpose, otherwise it will be discarded.

3.2 Acceptance Determination

3.2.1 Thickness

The decision to accept the waterproofing membrane thickness will be based on the mean and standard deviation of the lot as outlined in Table 1.

(a) Case 1 - Lot mean is less than 4.0 mm

If the lot mean is less than 4.0 mm the entire lot is unacceptable. In such cases the Contractor shall repair the entire lot as outlined in 3.2.1.d below.

(b) Case 2 - Lot mean is greater than or equal to 4.0 mm and less than or equal to 6.0 mm

If the lot mean is greater than or equal to 4.0 mm and less than or equal to 6.0 mm, the mean and the standard deviation will be rounded to the closest 0.1 mm and 0.05 mm respectively, and will then be applied to Table 1 to determine if the lot is in the acceptable, borderline or unacceptable zone.

If the lot is within the acceptable zone of Table 1, a thickness payment adjustment factor of 1.00 will be applied.

If the lot is within the borderline zone of Table 1, the Contractor may repair the lot as outlined in 3.2.1.d below,

or he may request that the Ministry accept the lot as is, with a reduced payment.

If the lot is within the unacceptable zone of Table 1, the Contractor shall repair the lot as outlined in 3.2.1.d below. Once repaired the entire lot will be re-measured and re-evaluated for acceptance as described in this special provision.

(c) Case 3 - Lot mean is greater than 6.0 mm

If the lot mean is greater than 6.0 mm, regardless of the standard deviation, the Engineer will review the conditions that the bridge deck will be exposed to and then will designate the lot as acceptable, or as unacceptable. The reasons for designating the deck acceptable or unacceptable will be discussed with the Contractor; however, the

designation of the lot will be made by the Engineer.

When the lot is designated unacceptable, the Contractor shall repair the lot as outlined in 3.2.1.d below. Once repaired, the entire lot will be re-measured and re-evaluated for acceptance as described in this special provision.

(d) Repair of lot due to thickness deficiency

Whenever the Engineer identifies an unacceptable lot due to thickness deficiency, or whenever the Contractor chooses to improve a borderline lot, the Contractor shall make whatever repairs he deems necessary to upgrade the lot. Any protection boards that are removed shall be replaced with new ones. Once repairs have been completed the Contractor shall notify the Engineer and the Engineer will determine a new set of random locations and will re-measure and re-evaluate the entire lot for acceptance as described in this special provision.

3.2.2 Membrane Quality

The decision to accept the quality of the waterproofing membrane will be based on the results of tests performed in accordance with OPSS 1213.

Membrane quality will be considered acceptable if all specification requirements for the lot are met, or it will be considered borderline, and subject to a price adjustment as outlined in part 4.2, if the total number of points resulting from Table 2 are less than or equal to 25, or will be considered rejectable if the total number of adjustment points are greater than 25.

4.0 Basis of Payment

The final payment for the lot will be based on the thickness and on the quality of the waterproofing membrane. The contract price for the lot shall be multiplied by the thickness adjustment factor and the result shall then be multiplied by the quality adjustment factor.

4.1 Payment Adjustment for Thickness

(a) Acceptable Lot

If the lot is designated as acceptable the Engineer will assign a thickness adjustment factor of 1.00.

(b) Borderline Lot

If the lot is designated as borderline, the Engineer will apply the lot mean and the lot standard deviation to Table 1 to determine the thickness adjustment factor

4.1.1 Re-testing of Thickness

The Contractor may request re-testing if any or all of the ten sub-lot thickness test values are challenged. If this occurs, 10 new thickness measurements are to be taken within the lot by the Engineer in the presence of the Contractor. The new test values will then be used to determine acceptance, and the results will be binding on both parties. Re-testing shall conform to this special provision.

Table 1 - Payment Adjustment Factors for Bridge Deck Waterproofing Membrane Thickness

STANDARD DEVIATION	MEAN 4.0	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5.0	5.1	5.2	5.3	5.4	5.5	5.6	5.7	5.8	5.9	6.0	STANDARD DEVIATION
0.40	1.00																					0.40
0.45	.99	1.00																				0.45
0.50	.94	.99	1.00																			0.50
0.55	.83	.95	.99	1.00																		0.55
0.60	Una.	.86	.95	.99	1.00																	0.60
0.65		.59	.87	.96	.99	1.00																0.65
0.70		Una.	.71	.89	.96	.99	1.00															0.70
0.75			Una.	.76	.91	.96	.99	1.00														0.75
0.80				Una.	.81	.91	.96	.99	1.00	1.00												0.80
0.85					Una.	.83	.92	.97	.99	.99	1.00											0.85
0.90						.64	.84	.93	.97	.99	.99	1.00										0.90
0.95						Una.	.71	.87	.93	.97	.99	.99	1.00									0.95
1.00							Una.	.76	.87	.94	.97	.99	.99	1.00								1.00
1.05								Una.	.79	.89	.94	.97	.99	.99	1.00							1.05
1.10									.59	.81	.90	.95	.97	.99	.99	1.00						1.10
1.15									Una.	.64	.83	.91	.95	.97	.99	.99	1.00					1.15
1.20										Una.	.71	.84	.91	.95	.97	.99	.99	1.00				1.20
1.25											Una.	.76	.86	.92	.95	.97	.99	.99	1.00			1.25
1.30												Una.	.77	.87	.92	.95	.98	.99	.99	1.00		1.30
1.35													.59	.79	.87	.93	.96	.98	.99	.99	1.00	1.35
1.40													Una.	.68	.82	.88	.93	.96	.98	.99	.99	1.40
1.45														Una.	.71	.83	.89	.93	.96	.98	.99	1.45
1.50															Una.	.74	.84	.90	.94	.96	.98	1.50
1.55																Una.	.78	.86	.91	.94	.96	1.55
1.60																	.64	.79	.87	.91	.94	1.60
1.65																	Una.	.68	.81	.87	.91	1.65
1.70																		Una.	.71	.82	.87	1.70
1.75																			Una.	.74	.83	1.75
1.80																				.59	.76	1.80
1.85																				Una.	.64	1.85
1.90																					Una.	1.90
1.95																						1.95
2.00																						2.00
STANDARD DEVIATION	4.0	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5.0	5.1	5.2	5.3	5.4	5.5	5.6	5.7	5.8	5.9	6.0	STANDARD DEVIATION

MEAN

All empty cells below cells with pay factors form the unacceptable range

Table 2

Test	Specification Limits	Adjustment Points
Cone Penetration at 25°C	Max 110	0.1 per 1
Cone Penetration at 50°C	Max 160	0.1 or 0.2 per 1 *
Flow at 60°C	Max 3	0.5 per 1
Low temperature flexibility at - 25°C	Pass	5.0 for Failure
Toughness	Min 5.5	0.5 per 0.1
Toughness/Peak Load	Min 0.040	0.5 per 0.001

* If the Cone Penetration at 50°C is greater than 160 but less than or equal to 200 the factor is 0.1, or if it is greater than 200, the factor is 0.2 per unit that exceeds the specification limit.

4.2 Payment Adjustment for Quality

Quality Payment Adjustment Factors are calculated as follows:

(a) If the sample meets all test criteria outlined in Table 2, the Engineer will assign a quality adjustment factor of 1.00.

(b) If the sample fails one or more test criteria, the adjustment points outlined in Table 2 for each failed criteria shall be totalled. The Engineer will assign a quality adjustment factor which shall be 100 minus the total of all of the adjustment points and the result divided by 100.

(c) If the sample fails one or more test criteria, the adjustment points outlined in Table 2 for each failed

criteria will be totalled and if the total number of points exceeds 25 the Ministry will not pay the Contractor for the lot regardless of the the adjustment factor for thickness.

4.2.1 Re-testing for Quality

The Contractor may request re-testing of any sample which results in a price adjustment or rejection of a lot within 30 calendar days of receiving notification of rejection or price adjustment of the lot. The results of the re-test shall be used for acceptance and shall be binding on both parties. If the re-test results in either a price reduction or rejection of the lot ,the Contractor shall be charged $500.00 for the re-testing. If the re-testing results in the material passing all test criteria, no charge will be levied against the Contractor.

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